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The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

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RPPR Final Report
as of 23-Apr-2018

Agency Code:

Proposal Number: 60329NSPCS **Agreement Number: W911NF-12-1-0550**
INVESTIGATOR(S):

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DUNS Number: 044387793 EIN: 560532129
Report Date: 13-Dec-2017 Date Received: 12-Apr-2018
Final Report for Period Beginning 14-Sep-2012 and Ending 13-Sep-2017
Title: Computing Game-Theoretic Solutions for Security in the Medium Term
Begin Performance Period: 14-Sep-2012 **End Performance Period:** 13-Sep-2017
Report Term: 0-Other
Submitted By: Vincent Conitzer Email: vincent.conitzer@duke.edu
Phone: (919) 660-6503
Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees: 0 **STEM Participants:** 4

Major Goals: STATEMENT OF THE PROBLEM STUDIED

This project concerns the design of algorithms for computing game-theoretic solutions. (Game theory concerns how to act in a strategically optimal way in environments with other agents who also seek to act optimally but have different, and possibly opposite, interests.) Such algorithms have recently found application in a number of real-world security applications, including among others airport security, scheduling Federal Air Marshals, and scheduling US Coast Guard patrols. We aim to extend these techniques not only to new settings but also to temporally extended (multiperiod) models.

Accomplishments: SUMMARY OF THE MOST IMPORTANT PUBLISHED RESULTS (NOT INCLUDING ANY PAPERS
PUBLISHED PRIOR TO THIS REPORTING PERIOD, THOUGH FOR THE JOURNAL PAPER THERE WAS A SHORTER EARLIER CONFERENCE VERSION)

Computing optimal mixed strategies to commit to is a technique that has been at the core of various applications to security. The motivation is that the defender can build up a reputation for playing in a particular way, due to attackers being able to observe their actions. However, in practice, sometimes some of the defender's actions are not visible (even after the fact) to the attacker. Motivated by this, in a WINE'16 paper, I study what happens if the leading player is only partially able to commit, in that she can not prevent herself from reallocating probability among externally indistinguishable strategies.

With Duke Ph.D. student Yuan (Eric) Deng, we have been studying "disarmament games" in which players can iteratively remove parts of their strategy space (either by removing strategies directly or by removing the resources that allow them to play those strategies). The idea here is that such a removal can sometimes put another player in a favorable position to remove some of his strategies as well, in turn benefiting the former player

-- etc. However, plans to disarm need to be carefully designed to prevent a player from having an incentive to suddenly stop disarming and take advantage of the other player's disarmament so far. We have studied both the computational complexity of determining whether successful disarmament is strategically feasible, as well as general characterizations of when it is feasible, in AAAI'17 and AAAI'18 papers.

With recent Duke Ph.D. Yuqian Li, we published a JAIR'17 paper on how to strategically choose questions to put on a test. One motivation for this problem is a setting such as a driver's license exam where there is a set of possible questions and we wish to randomize which of them to put on the test; we do not want to put the same ones on the test each time because people would just memorize the answers, but on the other hand some questions may be more effective than others so we need to intelligently and strategically randomize instead of just doing a uniformly random draw. Besides the design of tests in the literal sense, the results also have application to the design of inspection regimes -- e.g., suppose we suspect certain sites of harboring illicit nuclear activity and are able to randomly inspect a few of them of our choosing.

With Duke Ph.D. student Catherine Moon, we are finalizing for submission a paper on a study with human subjects. In this study, we consider games that are repeated over time. We are interested in the extent to which, when the same set of agents (people) play multiple games in parallel (and repeatedly), we observe spillover effects -- meaning that play in one game affects play in another game. For example, a player may choose to sanction another player for bad behavior in one game by doing something disadvantageous to that player in another game. The specific context in which we investigate this is public good games. In economics, a public good is a good that it is hard to prevent someone from enjoying, even if he or she did not contribute towards it. Common examples include clean air, street lighting, and national defense. In a public good game, multiple parties can contribute (say) dollars to the public good, which results in larger total benefits but these benefits are equally shared, leading to a potential incentive to free ride off others' contributions. Our goal is to study under what conditions and how people will use bilateral relationships that are taking place in parallel to punish (along the lines of game theory's folk theorem) others for not contributing to the public good.

Training Opportunities: This project is contributing tremendously to the research and presentation skills of my research group members. I have also been mentoring each of them individually in weekly meetings, on research and presentations but also on the continuation of their careers.
Finally, the project is of course helping to improve my own research and teaching skills.
See elsewhere in this report for impacts on training through teaching, tutorials etc.

Results Dissemination: The primary means of disseminating the work has been through publication in top conferences and journals, as well as through talks in other venues (e.g., I gave a talk titled "Computing Game-Theoretic Solutions and Applications to Security" at RTI International in September 2016).

In Spring 2017, I taught (with postdoc Michael Albert) a graduate computer science topics course on computational aspects of game theory and mechanism design, also drawing students from other disciplines, as well as from Duke's interdisciplinary MS in Economics and Computation. Quality of course: 4.86/5.00, quality of instruction: 4.93/5.00, quality of instructor: 4.86/5.00.

Honors and Awards: Program co-chair, NetEcon 2017
One of the editors in chief of the ACM Transactions on Economics and Computation (completed second and final term)
AAAI Councilor (completed term)

Protocol Activity Status:

Technology Transfer: Milind Tambe's group at USC is involved in various real-world applications to security of these types of techniques, including through the company Avata Intelligence (formerly ARMORWAY) to which I now serve as an advisor. We hope that our work is beneficial to this effort.

PARTICIPANTS:

Participant Type: Graduate Student (research assistant)
Participant: Yuan (Eric) Deng
Person Months Worked: 5.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Catherine Moon
Person Months Worked: 5.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Rupert Freeman
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Andrew Kephart
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: PD/PI
Participant: Vincent Conitzer
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:

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International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

ARTICLES:

Publication Type: Journal Article Peer Reviewed: Y **Publication Status:** 1-Published
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Volume: 59 Issue: First Page #: 437
Date Submitted: 4/10/18 12:00AM Date Published: 1/1/17 5:00AM
Publication Location:
Article Title: Game-Theoretic Question Selection for Tests
Authors: Yuqian Li, Vincent Conitzer
Keywords: game theory, artificial intelligence
Abstract: Conventionally, the questions on a test are assumed to be kept secret from test takers until the test. However, for tests that are taken on a large scale, particularly asynchronously, this is very hard to achieve. For example, TOEFL iBT and driver's license test questions are easily found online. This also appears likely to become an issue for Massive Open Online Courses (MOOCs, as offered for example by Coursera, Udacity, and edX). Specifically, the test result may not reflect the true ability of a test taker if questions are leaked beforehand. In this paper, we take the loss of confidentiality as a fact. Even so, not all hope is lost as the test taker can memorize only a limited set of questions' answers, and the tester can randomize which questions to let appear on the test. We model this as a Stackelberg game, where the tester commits to a mixed strategy and the follower responds. Informally, the goal of the tester is to best reveal the true ability of a test taker, while the test
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Acknowledged Federal Support: **Y**

CONFERENCE PAPERS:

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Proceedings of the Seventh Innovations in Theoretical Computer Science Conference (ITCS-16)
Date Received: 02-Aug-2016 Conference Date: 14-Jan-2016 Date Published:
Conference Location: Cambridge, MA, USA
Paper Title: Timeability of Extensive-Form Games
Authors: Sune Jakobsen, Troels Sørensen, Vincent Conitzer
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence (AAAI-16)
Date Received: 02-Aug-2016 Conference Date: 12-Feb-2016 Date Published:
Conference Location: Phoenix, Arizona, USA
Paper Title: Computing Possible and Necessary Equilibrium Actions (and Bipartisan Set Winners)
Authors: Markus Brill, Rupert Freeman, Vincent Conitzer
Acknowledged Federal Support: **Y**

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Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Proceedings of the Twenty-Fifth International Joint Conference on Artificial Intelligence (IJCAI-16)
Date Received: 02-Aug-2016 Conference Date: 09-Jul-2016 Date Published:
Conference Location: New York, NY, USA
Paper Title: Catcher-Evader Games
Authors: Yuqian Li, Vincent Conitzer, Dmytro Korzhyk
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Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Proceedings of the Twenty-Fifth International Joint Conference on Artificial Intelligence (IJCAI-16)
Date Received: 02-Aug-2016 Conference Date: 09-Jul-2016 Date Published:
Conference Location: New York, NY, USA
Paper Title: Role Assignment for Game-Theoretic Cooperation
Authors: Catherine Moon, Vincent Conitzer
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Proceedings of the 17th ACM Conference on Economics and Computation (EC-16)
Date Received: 02-Aug-2016 Conference Date: 24-Jul-2016 Date Published:
Conference Location: Maastricht, the Netherlands
Paper Title: The Revelation Principle for Mechanism Design with Reporting Costs
Authors: Andrew Kephart, Vincent Conitzer
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 0-Other
Conference Name: Twelfth Conference on Web and Internet Economics (WINE-16)
Date Received: Conference Date: 11-Dec-2016 Date Published:
Conference Location: Montreal, Canada
Paper Title: Computing Equilibria with Partial Commitment
Authors: Vincent Conitzer
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 0-Other
Conference Name: Thirty-First AAAI Conference on Artificial Intelligence (AAAI-17)
Date Received: Conference Date: 04-Feb-2017 Date Published:
Conference Location: San Francisco
Paper Title: Disarmament Games
Authors: Yuan Deng, Vincent Conitzer
Acknowledged Federal Support: **Y**

Publication Type: Conference Paper or Presentation **Publication Status:** 1-Published
Conference Name: Thirty-Second AAAI Conference on Artificial Intelligence (AAAI-18)
Date Received: Conference Date: 02-Feb-2018 Date Published:
Conference Location: New Orleans
Paper Title: Disarmament Games with Resources
Authors: Yuan Deng, Vincent Conitzer
Acknowledged Federal Support: **Y**

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Nothing to report in the uploaded pdf (see accomplishments).